Remarks

Claims 1-73 and 101-129 are pending.

Rejections under 35 U.S.C. § 103(a)

In the Advisory Action mailed April 28, 2004, the Examiner maintained the rejection of the claims under Section 103(a), as follows:

1) Claims 1, 2, 3-9, 11-14, 16-19, 21-24, 26-28, 30, 31, 34, 35, 37, 38, 40-45, 49, 68, 71, 101-105, 112, 114, 116, 120 and 121 as obvious over Wang (US 2002/0155218) in view of Hu (USP 6,436,820);
2) Claim 115 as obvious over Wang and Hu with Leem (USP 6,436,820) or Japan '220 (Japan 5-267220).
3) Claims 10, 15, 20, 25, 29, 32, 39, 50-59, 61-63, 66, 67, 69, 70, 72, 73, 106-111, 113, 117-119, 122, and 123 as obvious over Wang and Hu with Leem or Japan '220.
4) Claims 36, 46, 47, 48, 64 and 65 as obvious over Wang and Hu with Doan (US 2001/0006240).
5) Claim 48 as obvious over Wang and Doan with Hu.
6) Claims 60 and 124-127 as obvious over Wang and Hu in view of "applicant's admitted prior art (AAPA)."

These rejections are respectfully traversed.

The Examiner maintains the rejection of the claims for reasons stated at pages 2-3 of the Advisory Action.

In particular, the Examiner stated that although Wang expresses a preference for a temperature less than 600°C for TiN deposition, the plasma treatment is a wholly different step, and — although Wang exemplifies a single temperature of 580°C for the plasma treatment step, one skilled in the art would employ Hu's temperature of 680°C for the plasma treatment in Wang with the expectation that "increased [sic] film stress would be obtained." (It is assumed the Examiner meant "decreased" film stress would be obtained.)

The Examiner assertion is in error. Neither Wang nor Hu teach that the use of a high plasma treatment temperature of 680°C will decrease film stress.

Hu teaches that cracks and film stress are avoided "if the thickness of the film being annealed does not exceed 400 Å" (col. 4, lines 51-54). Wang teaches that cracks and film stress are avoided by using a TiN deposition temperature of less than 600°C, and describes forming a TiN layer having a thickness "up to about 300 Å" which is plasma treated.[1]

The Examiner also stated that "Wang teaches this embodiment nonetheless, and disclosed examples and preferred embodiments do not constitute a teaching away from a broader disclosure or nonpreferred embodiments."

Contrary to the Examiner's statement, Wang does not teach a plasma treatment temperature of 700°C or greater. *As admitted by the Examiner*, Wang exemplifies a single temperature of 580°C:[2] (See Advisory Action at page 2, lines 4-5):

> "...The reference exemplifies a single temperature of the annealing step which is 580°C (Table 2 and [0045])."

Also contrary to the Examiner's citation of cases, the claimed temperature of 700°C does *not* "overlap or lie inside ranges" taught by either Wang or Hu. Wang teaches a plasma treatment temperature of 400-600°C — which is a *100°C* difference. Hu teaches a plasma treatment temperature of 680°C — which is a *20°C* difference.

The Examiner further states that Hu is relied on as "providing motivation to employ the recited temperature in view of the disclosed use of about 680°C." The Examiner also notes that the purpose of Wang's process is to remove chlorine which would lead one to the claimed temperature range of 700°C or greater.

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[1] See [0033]: "...Cracks being to develop in these films that are about 400 Å thick...TiN film stress can be reduced by lowering the deposition temperature..." See [0035]: "...1) a relatively low deposition temperature of less that about 600°C ..." See [0039]: "...and a pedestal temperature is maintained at about 400-600°C... See [0042]: "...In particular, the TiN layer 204, e.g., having a thickness up to about 300 Å..."

[2] Table 2 indicates a plasma treatment (pedestal) temperature of 580°C as preferred and a range of 400-600°C.

First of all, the Examiner simplifies and mischaracterizes the purpose of Wang's process. Wang's stated objective is to provide a method of *depositing TiN at a reduced temperature* to provide a *thick and crack-free* TiN film having *low resistivity*. See [0010] and [0011]:

> [0010] Therefore, a need exists in the art for a method of depositing TiN at a reduced temperature, to yield thick, crack-free TiN films having improved properties including good step coverage and low resistivity.
>
> SUMMARY OF THE INVENTION
>
> [0011] The present invention is a method of forming a titanium nitride (TiN) layer using a reaction between ammonia (NH_3) and titanium tetrachloride ($TiCl_4$) at a pressure of about 10 to about 50 torr and a temperature of less than about 600°C., followed by treating the TiN layer in a hydrogen-containing plasma.

Second, there is no motivation to increase the plasma anneal temperature of Wang as proposed to 700°C or greater.

Hu teaches plasma annealing at 680°C. Wang teaches a plasma treatment at 580°C or a range of 400-600°C. Applicant claims heating the contact at 700°C or greater.

Although the TiN deposition step is different than the plasma treatment step, the various teachings of Wang that emphasizes the use of a low temperature TiN deposition step (i.e., 400-600°C) provide motivation to maintain the plasma treatment temperature at a comparable temperature. For example, Wang emphasizes:

a) avoiding a TiN deposition temperature over 650°C [0033];

b) the problem of atomic inter-diffusion within the capacitor structure when thermal CVD of TiN is performed at about 650°C [0009];

c) the need for a method of depositing TiN at a reduced temperature [0010]; and

d) forming the TiN layer at a temperature of less than 600°C [0011].

In view of the teaching of the importance of a deposition temperature of less than 600°C, one reading Wang's disclosure would not be motivated to then utilize a 700°C plasma treatment, particularly where Wang teaches a *plasma treatment* at 580°C or a range of 400-600°C — which is *80°C lower* than taught by Hu, and *100°C lower* than claimed by Applicant.

There is additional motivation to maintain the plasma treatment temperature of Wang at the same temperature as the TiN deposition — based on Wang's disclosure of forming a TiN film that is greater than 300 Å by repeated cycles of TiN deposition and plasma anneal. Wang teaches the importance of limiting the deposited TiN film to a thickness of 300 Å ([0022], [0042]) to avoid cracks that develop in films that are greater than 400 Å [0007]. To form a thicker TiN layer, Wang teaches *repeating several cycles* of film deposition and plasma treatment.

Thus, in using repeated cycles to form a film thicker than 300 Å, the Examiner's proposed incorporation of a plasma treatment temperature of 700°C or greater into Wang's process would necessitate a *cooling step* prior to Wang's TiN deposition step at the required temperature of less than 600°C [Wang at 0011] — meaning a *significant* cooling to *reduce the temperature from 700°C to 600°C* — which is a reduction of *at least 100°C*.

Clearly, one skilled in this art area reading Wang's disclosure would not utilize a plasma temperature greater than 700°C in Wang's process since it would require a *100°C* reduction in temperature before a subsequent TiN deposition could be performed at the less than 600°C deposition temperature expressly taught by Wang.

The disclosure in Wang of sequentially performing the TiN deposition and plasma treatment steps to form a TiN film greater than 300 Å provides further support against the Examiner's proposed modification of Wang to increase the plasma anneal from 580°C to 700°C. That disclosure taken with Wang's teaches of a low deposition temperature would motivate a skilled art worker employing Wang's process to maintain a low plasma anneal temperature and would not be motivated based on Hu's disclosure to raise the plasma anneal temperature to either 80°C or 100°C.

In sum, Wang, either alone or combined with Hu, does not teach or suggest Applicant's method involving the step of heating a contact in a reactive gas at a temperature of 700°C or greater to remove an adverse component (e.g., chlorine) from the contact. Accordingly, withdrawal of the rejections of the claims is respectfully requested.

Further, nothing in either Wang or Hu teaches or suggests a method of forming a contact comprising *boron-doped* titanium nitride (titanium boronitride), as recited in Claims 10, 15, 20, 25, 29, 30-32, 39, 50-67, 69-70, 72-73, 105-108, 110, 113, 115, 117-119, 122-123, and 128-129.

Such contacts overcome problems of pure $TiCl_4$-based titanium nitride plugs or barrier film by incorporating boron, which has been found to improve the mechanical properties of a titanium nitride film with substantially no impact on its conductive properties. Boron in the contact provides the contact with a high level of adhesion to insulative sidewalls of an opening to eliminate peeling of the contact from the sidewalls, and the nitrogen to maintain the conductivity of the contact at a predetermined level for an effective electrical contact with a conductive or active area within the substrate. (Specification at page 3, lines 3-15.)

The Examiner has failed to establish a *prima facie* case of obviousness based on the primary references of Wang and Hu, due to a clear lack of motivation to combine those references. As for the further disclosures of the secondary references — Leem (USP 6,436,820), Japan 5-267220 (Japan '220), and/or Doan (US 2001/0006240) — those references do not make up for the deficiencies of the Examiner's rejection.

In sum, there is no motivation to combine the teachings of Wang and Hu, and the teaching of any of the secondary references does not make up for the lack of motivation to combine the primary references, or the above-stated deficiencies of the Examiner's rejections of the claims based on Wang and Hu.

Accordingly, the Examiner has not established a *prima facie* case of obviousness of the claims at issue, and withdrawal of the rejections of the claims is respectfully requested.

Extension of Term. The proceedings herein are for a patent application and the provisions of 37 CFR § 1.136 apply. If any extension of term is required, please consider this a petition therefor. If any extension fee is required, please charge Account No. 23-2053.

It is submitted that the present claims are in condition for allowance, and notification to that effect is respectfully requested.

Respectfully submitted,

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Dated: June 4, 2004

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